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SAFETY CONSIDERATIONS

FOR

IN-LINE MECHANICAL FUZES

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1. INTRODUCTION

A fuze is a device designed to initiate an explosive charge. Thus all explosive devices contain a fuze and since the fuze is responsible for initiating the explosive it normally contains safety features which are designed to prohibit initiation until the weapon has been deployed and has achieved a safe separation distance from the launcher platform.

For most conventional fuzes these safety features are embodied in a safe-arming unit (SAU) which keeps the initiator in a position where it cannot initiate the main charge until correct deployment and safe separation are achieved. Such systems are 'out of line' when safe and 'in line' when armed. Safety principles for these systems are well documented and have a long history of acceptable performance.

A more recent development is in-line electronic fuzing. These systems do not employ any sensitive explosives but use an electrically produced shock to initiate a secondary explosive. Such systems require extremely high power inputs and the SAU ensures that such a firing pulse cannot be delivered to the detonator until safe separation has been achieved. There is general agreement about the safety principles for such systems and in many respects they are similar to out-of-line fuze safety principles.

A large group of explosive initiation systems contain no safe arming unit. They are in effect in-line and are typically initiated either mechanically or electrically. Such systems have a significant risk of unintended functioning and it is common to employ operational constraints and procedures to reduce the risk of unintended initiation to an acceptable level. Examples of such a system are primed cartridge

cases and rocket motor igniters either electrically or mechanically initiated. The hazard of such a system may be quite low (small arms) or critical (large calibre shell). Electrically initiated devices are susceptible to various electromagnetic inputs including RADAR, electrostatic and other induced RF energies. In many instances quite low energies or powers can initiate the primer (10 J or 200 mW are typical) and various procedures are required to eliminate electrostatic and limit the RF environment so that the risk (probability of an unintended initiation) and hazard are kept within acceptable bounds.

2. PYROTECHNIC INITIATED EXPLOSIVES (PIE)

Australia, primarily the Royal Australian Airforce, are interested in procuring Raufoss MP70A1 20 mm ammunition (figure 1). This ammunition contains an initiation system which is mechanically initiated upon impact and does not include a safe arming unit. The initiation system is considered to be an In-Line Mechanical Fuze.

The Australian Ordnance Council (AOC) is required to establish safety criteria against which the ammunition could be assessed for safety and suitability for service. The currently accepted criteria for projectile fuzes [1,2] are of little relevance as they address only electronic in-line fuzes and out of line fuzes.

3. DESIGN SAFETY PRINCIPLES FOR IN-LINE MECHANICAL FUZES

A set of Design Safety Principles for in-line mechanical fuzes has been developed and promulgated as AOC proceeding 119/85. The major departures from similar principles for out of line fuzes are

(a) The absence of clauses relating to interuptors and shutters.

(b) The absence of clauses relating to safe separation distances.

(c) The inclusion of a clause relating risk and hazard.

(a) and (b) are clearly not appropriate to a system which has been designed with the intention of providing adequate and acceptable safety without shutters and safe separation systems. The major changes to conventional fuzing safety philosophy is the inclusion of hazard in the consideration of fuze safety.

4. HAZARD CATEGORIES

DEF STAN 08-3 gives the following qualitative hazard categories.

Category 1 - Catastrophic. May cause death or system loss.

Category 2 - Critical. May cause severe injury, severe occupational illness or major system damage.

Category 3 - Marginal. May cause minor injury, minor occupational illness or minor system damage.

Category 4 - Negligible. Will not result in injury, occupational illness or system damage.

Design goals for conventional out of line fuzes are:

Safety system failure less than 1 in 10^6

Performance failure less than 1 in 10^3

No distinction is made on the basis of hazard. Thus a 20 mm projectile requires the same level of protection as a 155 mm shell and a 1000 kg bomb. This is probably a sensible approach as sympathetic detonation is an important factor in determining hazard.

PIE ammunition often contains low explosive loadings and little or no chance of mass explosions. This is true for Raufoss MP70A1 20 mm ammunition.

5. RELATIONSHIP OF RISK AND HAZARD

The accepted design goal for conventional fuzes of less than 1 in 10^6 for safety system failure is associated with stores which have a catastrophic hazard; this is an obvious criteria to apply to PIE ammunition given that a catastrophic hazard exists. At the other extreme of hazard category - negligible - a strong argument can be made for applying the performance failure rate goal of less than 1 in 10^3. Intermediate hazard categories, critical and marginal, were assigned safety system failure rates of 1 in 10^4 and 1 in 10^5 respectively. These latter two relationships were somewhat arbitrary but it is

interesting to note that Brigadier MacKenzie Orr [3] came to similar conclusions and gives some statistical basis to the proposed relationship. Table 3 is reproduced from [3].

TABLE 3

Table of Acceptable Probabilities vs Effects of Malfunction of Weapon Systems or Explosives Ordnance

EFFECT	ACCEPTABLE PROBABILITY OF OCCURRENCE PER EVENT
1. Catastrophic - Loss of life or total major equipment loss	1 in 10^6
2. Major - Serious injury or serious equipment damage	1 in 10^5
3. Minor - Injury causing temporary incapacitation or equipment damage requiring repair	1 in 10^4
4. Negligible - Temporary discomfort or inconvenience or minor degradation in equipment performance	1 in 10^3

6. SENSITIVITY OF EXPLOSIVE MATERIALS IN PIE AMMUNITION

The bench mark for explosives which may be used unshuttered in conventional fuzes and projectiles is tetryl. Explosives more sensitive than tetryl require shuttering. This is considered to be a reasonable design principle for PIE ammunition. The problem with this approach is defining what constitutes an explosive more sensitive than tetryl.

Qualification testing of an explosive involves a large number of sensitivity test including

(i) Friction

(ii) Impact - Figure of Insensitivity (F of I)

(iii) Temperature - Ignition temperature

(iv) Electrostatic

(v) Thermal Stability

(vi) Explosiveness

(vii) Fragment Attack, bullet impact

(ix) Cook-off

(x) Shock - Gap Test

Such tests are quite good for ranking high explosives in terms of sensitiveness or likelihood of unintended initiation, i.e. in order of least sensitiveness.

TATB-TNT-Comp B (RDX/TNT)-Octol (HMX/TNT)-tetryl-RDX-HMX-PETN

This ranking will not be true for each test but is arrived at by considering the reaction of a given explosive to a range of stimuli.

Pyrotechnic materials have performance and sensitiveness characteristics quite different from high explosives. They tend to be more sensitive to friction and impact and less sensitive to temperature and shock. The criteria that pyrotechnics which are more sensitive than tetryl should not be used unshuttered in PIE ammunition is thus considered a good design goal but unfortunately one which is difficult

to quantify. A better judgement of which pyrotechnic materials are satisfactory unshuttered in PIE ammunition will be possible when a data base is available on PIE systems with a satisfactory service history. Until such information is available it is considered that the most relevant sensitiveness test is impact (F of I) and unless the materials are less sensitive than tetryl (F of I = 90) statistical data will be required to demonstrate that the risk of premature initiation lies within the bounds detailed in para 5.

SUMMARY

1. Pyrotechnic Initiated Explosives (PIE) ammunition is considered to contain a mechanical in-line fuze.

2. Such systems are in principle similar to unshuttered electrically and mechanically initiated explosive systems currently in service.

3. Design principles have been proposed for mechanical in-line fuzes.

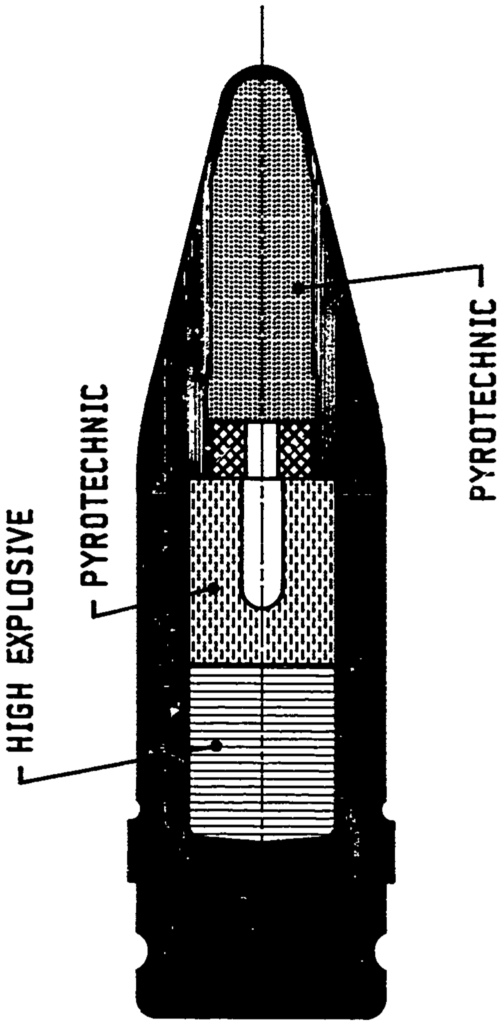
4. Tests are in hand to evaluate Raufoss 20 mm MP70 ammunition against these principles to determine safety and suitability for service.

REFERENCES

1. US Department of Defense (1984). "Military Standard. Fuze, Design Safety, Criteria For," MIL-STD-1316C.

2. UK Ordnance Board (1976). "Design Safety Principles for All Non-Nuclear Weapons Except Land Service Mines and Demolition Stores," OB Proc 41626.

3. First Australian Explosive Safety AOC Seminar, November 1985.



20mm PIE PROJECTILE